# HYBRID MICROCIRCUIT FABRICATION

# AND

# ANALYSIS STUDY

NASA CONTRACT NO. NAS8-25180

6764

N71 36624

FINAL PROGRESS REPORT

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### I. INTRODUCTION

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## A. OBJECTIVES

Under NASA Contract NAS8-25180 Electronic Communications, Inc. has performed a program with the objectives of establishing processes, quality and reliability techniques, and screening techniques for the implementation of face down bonding techniques in high reliability applications for hybrid microelectronics. The utilization of beam leaded devices and flip chip devices in a modified version of the ECI Model #940 DC Amplifier Power Supply provided a practical application to explore bonding procedures, inspection criterion, and reliability testing for face down bonding techniques.

### 1.0 General Requirements

Develop and conduct a program to collect, generate, and evaluate data and information necessary to establish processes, quality and reliability standards, and screening techniques for six (6) power supply sections of the ECI Model #940 Amplifier with revisions to include beam lead and flip chip technology in lieu of the present carrier mount configuration. The evaluation program will include six Model #940 DC Amplifiers (previously qualified) to provide direct comparison data with the beam lead/flip chip power supplies.

### 2.0 Mechanical Specifications

a. Hermetically sealed

b. Header with printed circuit pins and stud mounting

c. Dimensions: 0.780 inch x 0.810 inch x 0.480 inch

d. Volume: 0.303 $in^3$

e. Weight: 0.384 oz.

## 3.0 Environmental Specifications

a. Temperature: -55°C to +125°C (operating)

b. Vibration: 50 g peak 200 - 2000 Hz with a 15 minute logarithmic sweep in each direction (X,Y, & Z planes)

c. Altitude: less than $1 \times 10^{-7}$ cc/sec

d. High Temperature Operation: Each unit shall be operated for 240 hours at a case temperature of 125°C

## 4.0 Fabrication Processes

a. Alumina substrates

b. Metallization: Gold thin film for gold beam leads

Aluminum thin film for aluminum flip chips

Palladium gold thick film for solder flip chips

c. Nichrome thin film resistors

d. Component bonding:

Beam Leads: T.C. bonding

Al Flip Chips: Ultrasonic bonding

Ag/Tn Flip Chips: re-flow solder

Passive components & Substrate Mechanical Bonding: non-conductive adhesive bonding.

e. Wire Bonding:

1 Mil gold wire T. C. bonded

1 x 5 mil gold ribbon parallel gap and pincer welded

4 and 5 mil gold transformer wires parallel gap welded

f. Header Cover Sealing: re-flow solder seal in inert gas glove chamber

B. <u>RESULTS</u>

Six modified DC Amplifier power supplies with beam leaded and flip chip devices were assembled and qualified to the environmental requirements.

A comprehensive step stress program was performed on the power supplies and Model #940 DC Amplifiers.

C. <u>PROGRAM DEVELOPMENT</u>

During the period of substrate layout for dc amp power supplies the development of bonding techniques for the various devices was being carried out under NASA Contract NAS8-25615. The results of that program were used during the construction of the modified power supplies. The bonding techniques section of NAS8-25615 is included as part of this final report to provide an overall understanding of the face down bonding technology from a device level to the final screening of a completed assembly.

1.0 <u>BONDING DEVELOPMENT GOLD BEAM LEAD DEVICES</u>

One of the main goals of the program was to investigate various methods of assembly techniques used to fabricate hybrid circuits utilizing beam leaded devices. The two bonding techniques of single beam bonding and simultaneous beam bonding were investigated with the most effort placed on the least tried method of thermo-compression bonding a single beam at a time.

This method, when using pulsed heated tips, has the least effect on other devices on the hybrid circuit. The pulse heated tip may be the only way to bond beam leads on hybrid circuits having temperature sensitive devices, since wobble head bonding utilizes a heated stage during bonding.

Another important goal was to compare the various methods of testing the bond strength developed by the various bonding techniques. The air-blast method was refined by the Bell Telephone Laboratories and is well documented in published technical literature. It was decided that more information would be obtained for comparison by concentrating on a method where the beam leaded device was either pushed or pulled off of the bonded substrate. Either of these methods are more practical to most hybrid companies without any large capital expenditures.

Gold beam leaded devices were designed with the thermocompression bonding processes as the method for interconnecting these devices into circuits. An extension of this design is to utilize gold films to maintain a monometallic bonding system which is ideal for thermocompression bonding. The bonding studies were made with Raytheon RM 709BL beam lead devices having a Pt-Ti-Pt-Au metallization system. The beams are electroplated to a final thickness of 0.5 mils in a controlled gold plating bath. The RM 709BL is an integrated circuit having 14 beam leads uniformly distributed around its perimeter.

Another aim of the project was to determine what the failure mechanism would be for the beam lead devices. It was important to note the frequency of each type of failure and to try to understand what caused each type of failure. Once this data were obtained, the bonding parameters would be studied to determine how they relate to each failure mechanism. Finally a bonding schedule would be derived that would result in an optimum bond for a high reliability hybrid circuit.

The advantage of cold substrate bonding is obtained by pulsing a tungsten alloy tip with a controlled pulse of energy. The type of bond formed will depend on the bonding pressure, temperature, pulse duration and the configuration of the bonding tip. The widest range of satisfactory metallurgical bonds are achieved when the bonding temperature is 350°C ± 25° and the pulse width is 1.7 sec ± 0.2 sec. These two parameters were maintained in their respective range while the bonding pressure was varied for each type of bonding tip. The three bonding tips:

1. Slotted Wedge
2. Rounded Wedge
3. 0.0007" Capillary

were investigated to determine the most compatible type for bonding beam devices. Satisfactory bonds were achieved with all three types of tips. The amount of bonding force was much lower for the rounded wedge and the capillary tips. This is due to the type of beam deformation caused by the shape of the tip that comes into contact with the beam. The rounded wedge and the capillary tips were optimized at a bonding force of 40 gms ± 5 gms. The amount of diffusion was decreased as the force was decreased and if lowered enough would result in a weak bond or no bond. As the force is increased much above 45 gms the beam becomes pinched off at the heel of the tip and develops a weak point in the beam. Corresponding effects occur with the slotted wedge tip at forces of 60 gms ± 10 gms.

All three types of tips caused the chip to raise up, called "bugging," when the first beam was bonded. The degree of bugging depended on the bonding force and the type of tip. The higher the bonding force the more deformation of the beam and therefore resulting in more bugging. The more narrow the bonding tip the worse was the bugging. Since the capillary tip creates a circular deformation coplanar with the beam, the degree of bugging is decreased. The best processing control was obtained when the first two bonds were made on beams that were diagonally opposite each other on the chip. This prevented an excessive amount of bugging during the remaining bonds and prevented any alignment problem that might otherwise exist.

The improper location of the bond on the beam with respect to the chip will frequently cause failures. If the bond is made too close to the chip, the beam may break at the chip periphery. Thermal shock may occur to the thin film on the substrate if the bond tip extends much beyond the outer end of the beam. The optimum location for a bond made with a capillary tip is several tenths of mil from the outer edge of the beam.

The number of repairs that can be successfully performed depend on the film metallization and the type of substrate used for the hybrid. Bonds with beam diffusion into aluminum films are difficult to remove. The beams are easier to remove from a gold thin film and results in higher yields. Hybrid substrates with the thin film on a glazed surface are more difficult to remove the beams because of possible high stresses created in the glaze at time of beam removal. Occasionally the glaze will chip out of the substrate and create a discontinuity in the circuit. If the beams are not completely removed the alignment of the next beam lead device may be difficult.

A difference in bonding pad heights occurs where some beams are removed and some beams are allowed to remain on the substrate. This often causes some beams on the replacement device to break off at the chip during bonding.

Some bonding experience was developed with a Micro-Tech beam lead bonder using the multiple beam bonding process. The model 1190 Wobble Head Bonder was used for all the testing. This bonding uses a heated substrate stage and a constant heat bonding tip (cullet). The best bonds visually were bonded at the following setting:

1. Substrate temperature - 125°C
2. Cullet temperature - 390°C
3. Bonding force - 275 gms
4. Number of cycles - 2 or 3
5. Wobble speed - slow

Bond strengths comparable to the bonds made with a capillary tip were achieved with a minimum amount of effort.

The bond strength and type of failure mechanism depends on the method of mechanical testing used to remove the devices.

Two methods of testing bond strengths were evaluated. Either the device is sheared or pushed off the substrate. The shear-test is performed with a force applied along the plane of the beams. This test provides readings which range from 250 to 300 gms for a 14 beam leaded device. The shear-test appears to be less sensitive to bonding parameters since the bond strength is essentially the same for bonds made with 40 to 80 gms bonding force.

The "push-test" is achieved by applying a force perpendicular to the chip on the bonding face of the device. This is accomplished by inserting a 10 mil tipped needle through a 20 mil hole in the substrate. A pushing force is applied on the device until a catastrophic failure occurs. The push-test appears to be more sensitive to bonding parameters and gives bond strength readings approximately one-quarter the value of the shear-test. The explanation for both of these results is the type of failure mode is entirely different for the push-test than that for the shear-test. The four main modes for bond failure are[1]:

1. The peel strength of the bond - the force required to peel the beam from the substrate or silicon chip at an angle to the plane of the bond.
2. The buckling strength - the force required to buckle the beam.
3. The tensile strength of the beam - the force required to fracture the beam in tension.
4. The shear strength of the bond - the force required to shear the beam from the substrate or silicon chip.

The peel strength is given by Elftherion at an angle of 90 degrees (90°). Buckling and tensile strengths are several time stronger than the peel strength. Shear strengths are an order of magnitude stronger than the peel strength. The main mode of failures for the shear-test is tensile strength while the main mode of failures for the push-test is a combination of peel and tensile strength. Most beam failures occur at the bonds edge where the beam has a reduced cross-section, but the difference in the failure modes causes the push-test to fail at lower strength readings.

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Ref. (1) Handling and Bonding of Beam-Lead Sealed-Junction Integrated Circuits - M. P. Elftherion.

Beam lead devices can be bonded to unheated substrates by various pulse heated tips. The capillary tip creates a slightly stronger bond and has a higher yield than the wedge tips. The higher yield is mainly because the round capillary tip does not have the excessive bugging that occurs in the wedge bonds. The multi-beam bonders (wobble head) are more repeatable and much faster once the equipment is aligned and calibrated. It is recommended that for large quantities of beam lead devices that a multibeam bonder be used for bonding.

The method of testing the bonds will depend on the amount of equipment available. In theory the Bell System's air-blast test is the best method of testing bonded devices. This test stresses each beam uniformly and can be used as a non-destructive test. However, this equipment is extremely expensive and not commercially available. The most readily available equipment can be used to test beam lead bonds satisfactorily by either the shear or the push-test method. Either method cannot easily be used as a non-destructive test because the test visually creates some permanent damage to the device. The shear-test is the easiest and the less expensive but is not quite as sensitive a test as the push-test.

The common mode of failure for both the shear-test and push-test are broken beams occurring at the bond edge. This is due to the weakened area caused by the head of the bonding tip. Occasionally failures occur in the beam at the chip periphery and the bond frequently fails at the chip to beam interface. Whenever the bonding parameters are not kept within their range, the beams may break anywhere during the bonding process or a weak bond may result. The optimum bonding parameters for a capillary tip thermocompression bond are:

1. Temperature - 350- ± 25-C
2. Force - 40 ± 5 gms
3. Pulse width - 1.7 ± 0.2 sec
4. Bond made within a few tenths of a mil of the beam end.

The above parameters were used to bond approximately 150 Raytheon RM 709 BL integrated circuits with satisfactory results.

## ALUMINUM BEAM LEAD DEVICES

The device used to study aluminum beam lead bonding was a discrete transistor from North American Phillips. The 1.5 mil thick silicon chip is 10 mils square having four beams with a width of 2.5 mils, a length of 4 mils and a thickness of 0.25 mils. One of the main objectives of the program was to investigate various techniques for handling these devices prior to bonding. Any technique developed must not only be able to handle the very small devices but must be delicate enough not to damage the sensitive aluminum beam leads.

After the best handling tool was determined, the next goal was to determine what types of tools could be used for ultrasonically bonding the aluminum beams to aluminum thin film substrates. A bonding schedule would then be developed for each bonding tool that appeared satisfactory.

The minute size of the silicon chip makes the handling of the device extremely difficult. Many manual and semi-automatic systems were used without obtaining a method that gives consistent satisfactory results. A very fine vacuum needle was initially used to position the device onto the bonding pads for bonding. Alignment was difficult and very time consuming. A semi-automatic tool consisting of a capillary bonding tip with a 10 mil outside diameter and a 5 mil hole for the vacuum was satisfactorily used for positioning the device. This holder made it easy to align the device with the bonding pads and could be done quickly. The rotational alignment was the most difficult beacuse the substrate had to be rotated. This type of positioning tool would require the device to be temorarily attached at time of positioning to prevent movement until the beams were bonded permanently. It might also have been possible to use a turret type head (containing the pickup tool and the bonding tool) to make the bond right after device alignment to the substrate. This was not tried because of the complex tooling design required for the coupling of the ultrasonic energy to the bonding tool.

A handling tool that could be used for both positioning and bonding, such as are brazing cullets, was investigated. Several types of cullets were used with some success but the results were not consistent. Several cullets were too large and the vacuum would draw the chip into the cullet and bend the aluminum beams. The most appropriate tool was a 10 mil x 10 mil x 3 mil die brazing cullet from Micro-Swiss. Some difficulty was noticed in always picking up the device in the center of cullet such that all the beams were lying on the outer perimeter of the cullet. This misalignment could cause pinched off bonded beams.

The method of bonding the beams depended on what method was used to position the devices on the substrates. When the capillary tip was used to position the devices, a resin was used to temporarily hold the device in place. After the beams were ultrasonically bonded the resin was removed by dissolving it with alcohol and then flushing with filtered alcohol. Once the device was temporarily attached, the aluminum beam leads were bonded individually with the following types of tips:

1. 1 mil capillary
2. 5 mil capillary
3. Rounded probe with radius $\leqq$ 1 mil
4. Rounded dowel pin with radius $\leq$ 2 mils
5. Rounded wedge (Micro-Swiss #5006)
6. Flat wedge (Micro-Swiss #5007)
7. Slotted wedge (Micro-Swiss #5011)

The capillary tips and the wedge tips generally gave poor to fair bonds mainly because of the non-parallelism of the bonding tip face and the bonding pad. Bugging of the chip would occur when the temporary resin bond was not sufficient to hold the device during bonding. The rounded tips gave fair to good bonds. This type of tool does not rely on an alignment of bonding faces since it has a hemispherical bonding face. The probe tip produced a small bonding area and resulted in weaker bonds. The 2 mil rounded dowel pin gave the best single beam bonding and was the most consistent.

Multibeam bonding was performed with a Micro-Swiss 10 x 10 x 3 die brazing cullet (#604-TC). This tool provided relatively easy handling and positioning and also the capability of multibeam bonding. Good consistent bonds could not be made because of the non-parallelism of the bonding tool face and the substrate bonding pads. The limited amount of bonding indicated that the bonding parameters were:

1. Bonding force - 20 to 30 gms
2. Ultrasonic energy - 300 to 500 m watts
3. Bonding time - 200 to 400 milliseconds

The difficulty in the handling of the devices was the major problem with the aluminum beam lead device. Special tools would need to be designed for each device which might become very expensive. The approach taken by North American Phillips appears to have been well thought out. The equipment that they use for handling and bonding appears to have been designed to alleviate the problems that were encountered in the present program.

A rounded (hemispherical tipped) tool appears to be the best type of tool for bonding one beam at a time. The die brazing type of cullet would be satisfactory for multibeam bonding of both bonding surfaces were kept parallel during bonding or if the wobble head system would be adapted for these small devices. The North American Phillips approach is very similar to a two-sided die cullet with particular emphasis put on the parallel alignment of the bonding surfaces.

ALUMINUM FLIP CHIP DEVICES

Flip chip devices generally have three bumps for diodes and four bumps for transistors, while integrated circuits have 14 to 48 bumps. A four bump device (Intersil IT 930) was chosen as the test vehicle because it would have some of the alignment problems and could be tested electrically and mechanically with a reasonable amount of effort.

The first goal was to investigate the alignment problem and develop methods to alleviate the problem. The method would then be utilized to study the parameters of ultrasonically bonding the chip to an aluminum film on a glazed substrate. The strengths of the ultrasonic bonds would be measured and used to determine the optimum bonding parameters. The effects of typical flaws in the bumps would be investigated using the optimum bond schedule. The final objective was to determine if circuits using flip chips could be repaired.

The method of bonding the aluminum bump devices to the aluminum film would be to use a swept ultrasonic power supply. This type of supply sweeps over a frequency range (centered to 60 kilohertz) that will pass through the self-resonance frequency of the bonding system. This in turn eliminates the critical tuning of the power supply to the bonding tool.

The alignment problem was investigated initially so that it would be resolved before the bonding parameters were studied. Misalignment of the bonded bumps would affect the outcome of the results. The parallelism of the bumps to the substrate was difficult to determine visually. An angle of approximately 1 degree to 2 degrees is sufficient to have one bump not making contact with the substrate pad after bonding. A film of silicone mold release was sprayed on the substrate and used to align the bonding tool with the substrate. This was done by making a depression in the silicone film and adjusting the bonding tool until a uniform pattern was made in the silicone film by the bumps on the device. This method also was used to select the best types of pick-up and bonding tools. A die brazing type of cullet would not always pick up the chip in the same plane and would produce partial bonds and no bonds. The planarity of the bumps on the Intersil devices appeared to be controlled and the bump heights were within 0.1 mil on any one device. The substrates were glazed ceramic from coors and were sufficiently flat to cause very little alignment problems.

The best type of tool used to bond the flip chips would be one that could also be used for picking up the devices. This would eliminate many handling problems, such as, tedious handling and time consuming hand alignment. Several ultrasonic tools were tried that did not have a vacuum pickup capability to determine if there were any other problems characteristic of this type of tool. One problem that frequently occurred with a rounded dowel tip with a radius of 5 mils or less, was that the device would crack where the tip made contact with the chip. This generally occurred when high bonding forces (>400 gms) were used to get a satisfactory bond.

The best type of bonding tip was a Micro-Swiss 400-10 die cullet with a vacuum hole for picking up the devices. The face of the tool is the form of a flat ring with a 20 mil outside diameter and a 5 mil inside diameter hole. When the tip is aligned by the silicon film method, it will provide bonds with very few parallel alignment problems. The face of the tip must be cleaned frequently to prevent a build-up of foreign matter. The foreign matter can cause excessive movement between the tool and the chip during ultrasonic bonding.

The vertical alignment depends almost entirely on the skill of the operator. Where the chips are precisely scribed, the outer perimeter of the chip can be used as an alignment guide. This guide when used on a thin film pattern that matches the chip dimensions can result in good vertical alignment after bonding. Another technique, "reflective method," uses the bumps for alignment by observing the reflection of the bumps on the reflective thin film on the substrate. This method relies on the operator's skill and also can only be used on thin films that are reflective enough to see the image. The advantage is that the chip need not be scribed as accurate as in the first method. Another advantage is that the orientation can be checked just prior to the bonding. The reflective method was found to be the most practical and easiest to implement and produce satisfactory results. Another method of using infrared techniques to observe the alignment through the substrate was not tried. This method would have the advantage of seeing where the actual bond was made.

The main parameters in ultrasonic bonding are ultrasonic power, time, and applied to weight to the chip. The applied weight was varied from 125 gms to 600 gms with diffusion occurring over the whole range. It was found that the weight had to be near the top of the range to prevent the chip from spinning during bonding. The spinning could be as much as 45 degrees and make it impossible to maintain alignment between the chip and the thin film circuit. This was especially with the round bonding tools. One impression of the tool would be evident on the chip's backside when the weight was correctly set for a good bond. A weight of 400 gms was optimized when the Micro-Swiss 400-10 tip was used for bonding. Excessive weight would cause excessive deformation of the bumps and could cause the devices to short out electrically. The electrical shorts could be caused by the flattened bump bridging the thin film pattern on some devices, or the bumps shorting two adjacent bonding pads.

The amount of ultrasonic power will depend on the number of bumps on the device, the size of each bump, the type of bonding tool used and the type of power supply. The swept frequency power supply was used with the Micro-Swiss 400-10 bonding tool to bond the IT 930 devices. The power was varied from 2 watts to 20 watts. A minimum power of 3.5 watts was necessary to get the devices to adhere well enough to make shear test on them. The most consistent shear bond strengths were obtained with a power range of 7.5 watts to 16 watts. The optimum power was a function of time (pulse width). The lower the power the longer the time required to get a strong bond. The higher the power the shorter the time required to get a strong bond. While too short a pulse time would give a poor bond, too long a pulse time would cause the bump to shear from the device or the thin film may shear from the substrate. The optimum power and time settings were determined by the consistency of the shear bond strengths. An average bond strength of 150 gms was achieved for an optimum setting of 13 watts for 400 milliseconds.

A vacuum hold down is necessary to prevent the substrate from moving during bonding. At the higher power settings it is also necessary to keep the substrate holder clean to prevent movement of the substrate.

The flip chip devices require considerable care in parallel and perpendicular alignment. The silicone film method or a similar method can be used to align the chip's bumps to the thin film substrate. The perpendicular alignment can be made by one of several methods that rely on the skill of the operator. It is important that the alignment be maintained and periodically checked during a bonding program.

The best bonding tool is one that can be used for device handling as well as bonding. The ring faced tip that is smaller than the device provides satisfactory bonds. This type of tool must be kept clean during bonding to maintain the proper frictional force between the device and the tip face.

The bonding force must be sufficient to prevent the device from spinning and yet low enough to prevent damage to the device or an excessive deformation of the bumps. The amount of power will depend on the number of bumps and the size of the bumps. A four bump device with 5 mil diameter bumps requires approximately 13 watts from a swept frequency power supply. The pulse time must be sufficiently long enough to allow diffusion but not too long to prevent damage to the bond after diffusion is complete.

The strength of the bonds can easily be measured by a shear-test. An average of 150 gms was achieved for the four bump Intersil device. A minimum of 20 gms/bump should be easy to acquire.

## SOLDER BUMP FLIP CHIPS

The solder bump flip chip which was chosen for the program was a GAZ8075 zener diode from Hughes Semiconductor. The device has silver/tin pads and is a 20-mil chip. The geometry of the chip includes four pads (two anodes and two cathodes) which allowed ease in bonding. The solder bump chip resulted in the simplest bonding technique of the program.

The chips were bonded to thick film palladium-gold pads with a dielectric barrier to prevent excessive solder run-out along the remainder of the interconnect track. The thick film metallization is tinned using a 96 percent tin, 4 percent silver solder and is polished mechanically to obtain a uniform solder height. The flux used is Kester 1544. The devices are positioned and temporarily attached to the prefluxed pad using an ultrasonic bonder at low power and time. The reflow process is accomplished using a dry nitrogen gas jet at approximately 320°C with the substrate on a hot plate at 175°C. The isostrength diagram samples were shear-tested initially, after humidity, and after thermal shock. The initial shear values averaged 359 gms with a low of 55 gms and a high of 660 gms. After humidity the average 390 gms with a low of 100 gms and a high os 640 gms. After thermal shock the average was 539 gms with a low of 320 gms and a high of 770 gms.

Although the results of the solder bump chips seem to indicate very good bonds, ECI feels that for long term reliability the solder crack problems which have been investigated in printed circuit boards on the Apollo program may limit long term reliability results with solder bump chips.

## 2.0 RELIABILITY SCREENING PROGRAM

After the modified power supply assemblies were completed, a comprehensive reliability screening program was performed in order to evaluate the various techniques which were developed. The following section of the report indicates the reliability program which was performed on the power supplies and Model 940 DC Amplifiers. Reliability Report 1-2347.

# REPORT SUMMARY SHEET

| | |
|---|---|
| 1. COMPONENT/PART NAME PER GENERIC CODE: Microelectronic Circuit, Amplifier, Hybrid, Metal Encased, Plug In | 2. PROGRAM OR WEAPON SYSTEM: NASA |
| 4. ORIGINATOR'S REPORT TITLE: Section II.B (Reliability Program) of Final Report on "Hybrid Microcircuit Fabrication and Analysis Study | 5. ORIGINATOR'S REPORT NO.: 1-2347 A |
| 3. | DAY / MO. / YR. — TEST COMPL. 16 / 6 / 71; REPT. COMPL. 23 / 6 / 71 |
| | 6. TEST TYPE, ETC.: Environmental and Step Stress Testing |

7. THIS TEST (SUPERSEDES) REPORT NO: 1-2347

| 9 ITEM | 8A. PART TYPE, SIZE, RATING, LOT, ETC. | 9. VENDOR | 10. VENDOR PART NO. | 11. IND./GOV. STD. NO. | 12 TOTAL TESTED |
|---|---|---|---|---|---|
| 1 | D.C. Amplifier Power Supply S/N's 101 thru 106 | ECI | 03-02672 | | 6 |
| 2 | MOD 940 D.C. Amplifier, S/N's 112,114,117,119,122 | ECI | 03-02457 | | 5 |
| 3 | | | | | |
| 4 | | | | | (OVER) |

| 13. INTERNAL SPECS.ETC REQ'D TO UTILIZE REPT. | | ENCL | SENT WITH REPORT NO. | 14. MIL. SPECS./STDS. REFERENCED IN 15C | |
|---|---|---|---|---|---|
| A | GO 90110 | | | D | MIL-STD-810 |
| B | | | | E | |
| C | | | | F | |

| 15A. B ITEM | TEST OR ENVIRONMENT | C PER SPEC | D SPEC. PARAGRAPH/ METHOD/CONDITION | E TEST LEVELS, DURATION AND OTHER DETAILS | F NO. TESTED | G NO. FAILED |
|---|---|---|---|---|---|---|
| 1 | Temperature | A | 1.4.4 (a) | +25°C,+125°C,+25°C,-55°C,+25°C | 6 | 0 |
| | | | | Stabilize at each temp. and take electrical measurements. | | |
| 1 | Fine Leak | A | 1.4.4 (d) | | 6 | 0 |
| 1 | Vibration Random | D | Meth. 514 | Figure 514-4, Curve K | 6 | 0 |
| 1 | Fine Leak | A | 1.4.4 (d) | | 6 | 0 |
| 1 | Shock | A | 1.4.4 (d) | 3 axes, 18 shocks total, 100 G, | 6 | 0 |
| | | | | 11±1 msec | | |
| 1 | Fine Leak | A | 1.4.4 (d) | | 6 | 0 |
| 1 | High Temp. Oper. | A | 1.4.4 (e) | +125°C, 240 hours | 6 | 1 |

(OVER)

16. SUMMARY OF REPORT, NATURE OF FAILURES AND CORRECTIVE ACTIONS TAKEN: Six (6) Mod 940 D.C. Amplifier Power Supplies (D.C.P.S.) were constructed using hybrid flip-chip beam lead techniques. The D.C. Amplifiers (D.C.A.) (units include a built-in D.C. Power Supply) used the U-Channel carrier, wire bonding techniques. This test evaluated these two hybrid fabrication methods. One D.C.P.S. (S/N 103) failed after 96 hours in the Hi-Temperature Operation Test.

Five D.C.A.'s were sent to ECI from NASA. Three of these five D.C.A.'s were step stress tested with three D.C.P.S.'s.

(OVER)

21 REPT NO 515.50.04.46.M4.01

| 17 TESTED BEYOND VENDOR CATALOG SPECIFICATIONS | 18. VENDOR INPUT LETTER / COPY OF REPT / ORAL | 19. SIGNED | 20. CONTRACTOR | SUBCONTRACTOR |
|---|---|---|---|---|
| YES ✓ | ☐ ✓ ☐ | [signature] | ECI | |





SPE 407

| 8 ITEM | 8A. PART TYPE, SIZE, RATING, LOT, ETC. | 9. VENDOR | 10. VENDOR PART NO. | 11. IND./GOV. STD NO. | 12 TOTAL TESTED |
|---|---|---|---|---|---|
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |

| 15A. 8 ITEM TEST OR ENVIRONMENT | C PER SPEC | D SPEC. PARAGRAPH/ METHOD/CONDITION | E TEST LEVELS, DURATION AND OTHER DETAILS | F NO TESTED | G NO FAILED |
|---|---|---|---|---|---|
| 1,2 Sine Vibration Scan | A | para. 1.5 | One sweep, vert. plane, 200-2000-2000Hz,50G, no elec. monitoring | 6 | 0 |
| | | | (3 P.S. and 3 D.C.A.) | | |
| 1,2 Vibr-Temp Step Stress | A | para. 1.5 | (3 P.S. and 3 D.C.A.) Step 1: +25°C 0 G sine | 6 | 1 |
| | | | Step 2: 0°C 10 G sine | 6 | ↑ |
| | | | Step 3: +45°C 10 G sine | 6 | See |
| | | | Step 4: +65°C 20 G sine | 6 | Summary |
| | | | Step 5: -15°C 20 G sine | 6 | |
| | | | Step 6: -30°C 30 G sine | 6 | |
| | | | Step 7: +85°C 30 G sine | 6 | |
| | | | Step 8: +105°C 40 G sine | 6 | |
| | | | Step 9: -45°C 40 G sine | 6 | |
| | | | Step 10: -55°C 50 G sine | 6 | |
| | | | Step 11: +125°C 50 G sine | 6 | |
| | | | 1 hour/step, 4 sweeps of vibration after temp. stabilization | | ↓ |

16. SUMMARY OF REPORT, NATURE OF FAILURES AND CORRECTIVE ACTIONS TAKEN: One D.C.A. (S/N 112) failed output null on the first step, however, testing was continued on all six parts. On the fourth step D.C.A. (S/N 112) failed another parameter. The output voltage dropped from 45 VDC to approx. 29 VDC. The unit stayed in this condition for the remainder to the steps.

For the mechanisms of the failures, conclusions and any appropriate corrective actions see the "Summary and Conclusions" section I.D. of the Final Design Report "Hybrid Microcircuit Fabrication and Analysis Study" of which this report is a part.

21 REPT. NO. 515.50.04.46.M4.01

TABLE OF CONTENTS



SPE-15A

1.0 REASON FOR TEST: To evaluate bonding techniques and processes used on the Mod 940 D.C. Amplifier Power Supply.

2.0 DESCRIPTION OF TEST SAMPLES: Five (5) D.C. Amplifiers S/N's 112, 114, 117, 119, 122 (with their own built-in U-Channel carrier constructed power supplies) and six (6) D.C. Amplifier Power Supplies, S/N's 101 thru 106 built using flip-chip/beam lead bonding techniques. All parts were manufactured by ECI.

3.0 DISPOSITION OF TEST SAMPLES: Returned to ECI Project Engineer in Space Instrumentation Design Engineering.

4.0 ABSTRACT, CONCLUSIONS, RECOMMENDATIONS

4.1 ABSTRACT: This report describes the testing which was performed on five (5) Mod 940 D.C. Amplifiers and six (6) D.C. Amplifier Power Supplies. The five amplifiers were constructed with U-Channel chip carriers. The amplifiers also had built-in power supplies using the same U-Channel carriers techniques. The six power supplies were constructed using beam lead/flip-chip semiconductor devices.

The prime purpose of this test program was to evaluate under varying stress conditions the flip-chip beam lead bonding methods and procedures. In order to have a comparison of the new method to the existing U-Channel method a reference was set up by testing at the same time with the power supplies a group of Mod 940 D.C. Amplifiers. If any failures occurred a ready comparison could be made to possibly establish a superiority of one method over the other.

As can be seen from Figures 1 and 2 (page 8) both types of the test units were subjected to the same environmental tests prior to the formal step stress program. However, the six DCA's had been environmentally tested by ECI on a previous NASA contract. NASA used one DCA for extensive testing and returned five units to ECI for the SST program.

At ECI, one D.C.P.S. S/N 103 failed catastrophically after the third day's exposure to the high temperature operating cycle. This power supply had previously exhibited anamolous behaviour during the temperature cycling test, with a shift $>2\%$ from 25°C to +125°C and a residual offset of $\approx 1.7\%$ from initial conditions on completion of the temperature cycling test. See data sheets 11, 16 and 17.

OPE-134

The environmental tests to which all the units were subjected were:

a. Temperature (pages 10 & 11 for ECI test of D.C.P.S.)

   1. Electrical at +25°C
   2. +125°C stabilization, then electrical
   3. +25°C stabilization, then electrical
   4. -55°C stabilization, then electrical
   5. +25°C stabilization, then electrical

b. Shock (page 13 for ECI Test of D.C.P.S.)

   1. 3 times each of 6 orientations
   2. 100 G @ 11±1 msec (sine)
   3. Electrical test

c. Vibration, Random (pages 14,15,16 for ECI Test of D.C.P.S.)

   1. 30 minutes/axis on 3 axes
   2. a) 5-100 Hz @ +12 dB/oct roll-off
      b) 100-1000 Hz @ 46.3 GRMS
      c) 1000-2000 Hz @ -12 dB/oct roll-off
      d) 1.5 $g^2$/Hz spectral density
   3. Electrical test

d. High Temperature Operation (page 16) for ECI test of D.C.P.S.)

   1. +125°C
   2. 240 hours
   3. Electrical, every 24 hours

e. Fine Leak - performed after each of the previous environments to validate the integrity of the package.

Three of the five good units from each of the types (D.C.A. and D.C.P.S.) were selected (first three good S/N's of each type) to go through the step stress program. See Figure 3 for the step stress profile (page 9 ). However, one vibration scan of 200-2000-200 Hz (sine) @ 50 G and +25°C was made prior to the formal profile to gain a degree of confidence in the units before the grilling temperature/vibration combination step stress test.

OPE-154

One D.C.A., S/N 112, failed output null with zero input after the first step. However, testing was not halted on the part. On the same part after the fourth step, the output voltage dropped on the plus (+) and minus (-) sides from 45 VDC to approximately 29 VDC with 9 volts input. The part was still not removed from testing. This D.C.A. did not change appreciably anymore. The remaining five parts passed all the step stress testing.

4.2 CONCLUSIONS AND RECOMMENDATIONS: For the mechanisms of the failures, the conclusions and recommendations, see the "Summary and Conclusions", Section I.D of the final design report (of which this report is a part) "Hybrid Microcircuit Fabrication and Analysis Study".

SPE-154

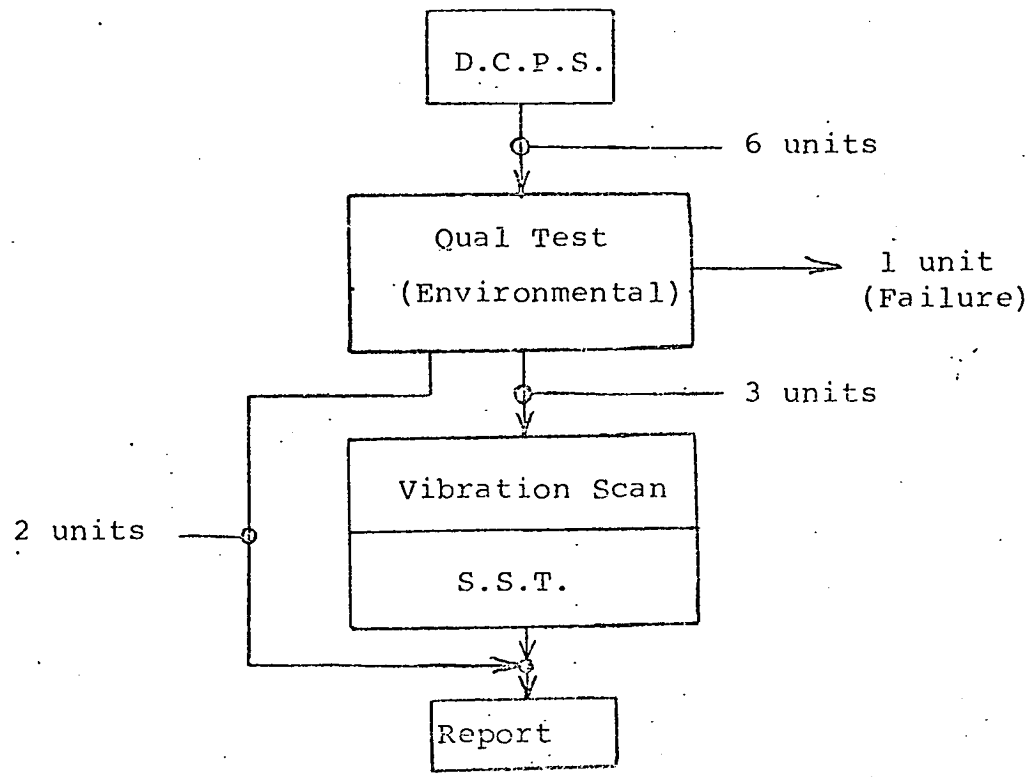
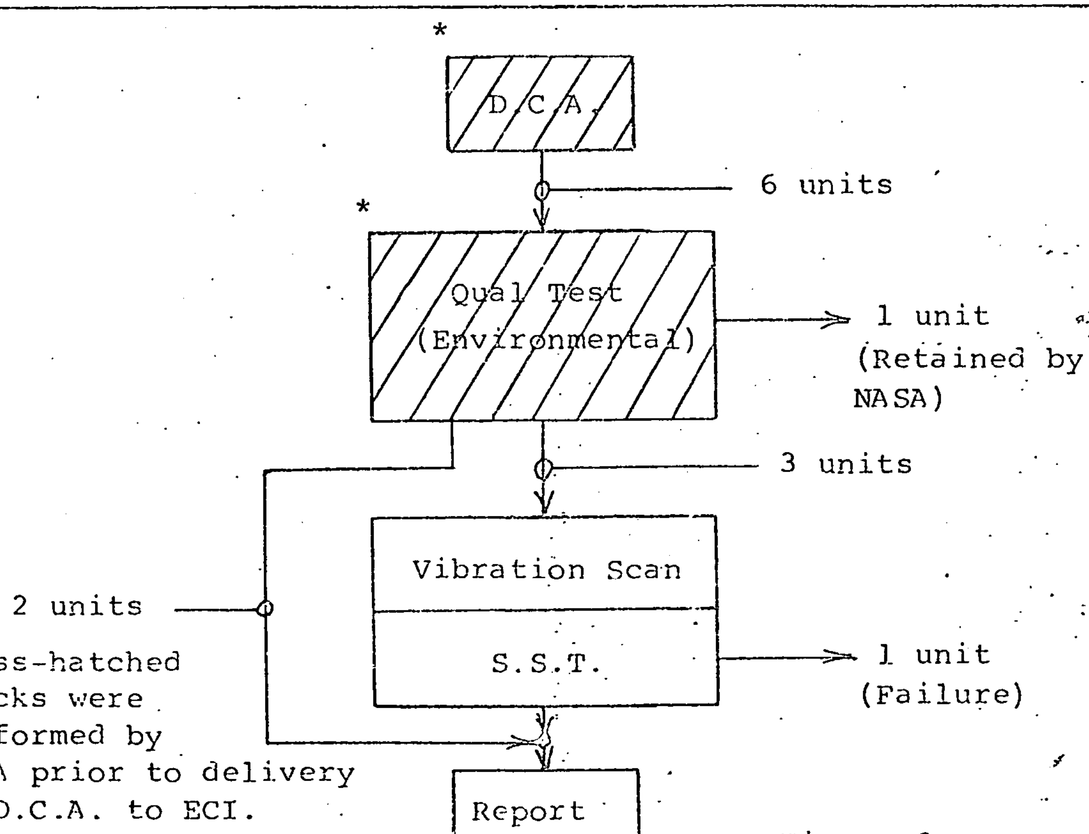



Figure 1




*Cross-hatched blocks were performed by NASA prior to delivery of D.C.A. to ECI.

Figure 2

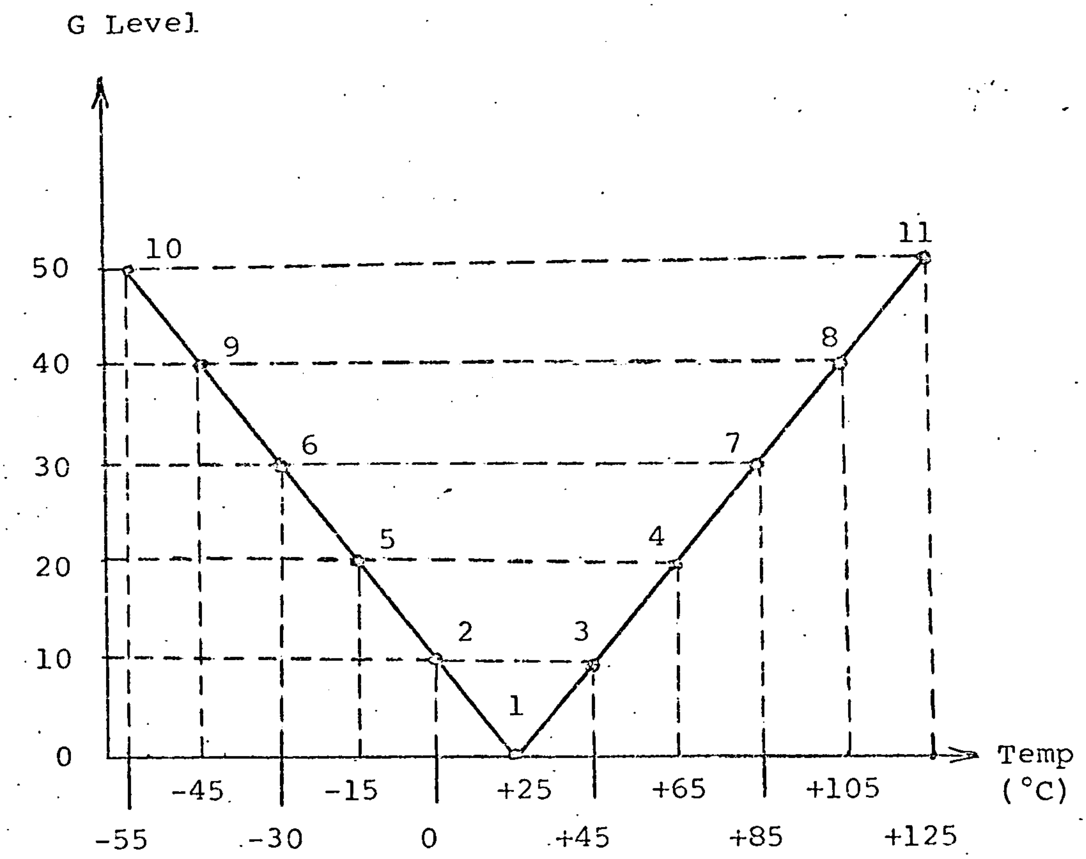



Figure 3



SFE-154

# TEST DATA SHEET

**Engineering Laboratory**

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

| | |
|---|---|
| TEST PERFORMED TEMPERATURE | DATE 23 MAR. 71 |
| E.C.I. PART NO. 03-02762 | TESTED BY [illegible] |
| MFR. NAME ECI | WITNESSED BY [illegible] |
| PART NAME DC [illegible] POWER SUPPLY | APPROVED BY |

1. Requirement TEMPERATURE TEST PER PARA 1.4.4 OF GO# N90110-1 PROPOSAL

2. Test Conditions
Relative Humidity PREVAILING Temperature AS SPECIF.

3. Results

4. Equipment Used

| Instrument | Mfr. | Model | Ser. | Cal. Date |
|---|---|---|---|---|
| DVM | H/P | 3440A | 11481 | 1-11-71 |
| POWER SUPPLY | HARRISON LAB. | 6226A | 430 | N.C.R. |
| TEMP. CHAMBER | A.T.L. | 2LH8 | 1036 | 6-15-70 |

SPE 255

# TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.

ST. PETERSBURG 10, FLORIDA

TEST PERFORMED TEMPERATURE
E.C.I. PART NO. 03-02762
MFR. NAME ECI
PART NAME DC AMP, POWER SUPPLY

DATE 23 MAR. 71
TESTED BY D. [illegible]
WITNESSED BY [illegible]
APPROVED BY

INPUT PINS 1-13 : 28.0 V.DC

OUTPUT LOAD PINS 9-12 : 10K Ω

| | | +25°C | +125°C | +25°C | -55°C | +25°C | TOLERANCE | |
|---|---|---|---|---|---|---|---|---|
| S/N | PIN# | ← OUTPUT VOLTAGE → | | | | | (VOLTS MIN.) | |
| 101 | 12 | 27.86 | 28.00 | 27.86 | 27.64 | 27.85 | + | 27.0 |
| | 9 | 25.14 | 25.21 | 25.13 | 24.97 | 25.13 | − | 24.0 |
| 102 | 12 | 28.26 | 28.39 | 28.27 | 28.07 | 28.26 | + | 27.0 |
| | 9 | 25.22 | 25.34 | 25.21 | 25.03 | 25.20 | − | 24.0 |
| 103 | 12 | 30.13 | 30.83 | 30.63 | 30.33 | 30.62 | + | 27.0 |
| | 9 | 27.17 | 27.53 | 27.34 | 27.07 | 27.33 | - | 24.0 |
| 104 | 12 | 27.96 | 27.99 | 27.96 | 27.83 | 27.95 | + | 27.0 |
| | 9 | 24.67 | 24.78 | 24.67 | 24.48 | 24.66 | - | 24.0 |
| 105 | 12 | 28.92 | 29.06 | 28.93 | 28.64 | 28.91 | + | 27.0 |
| | 9 | 25.77 | 25.90 | 25.77 | 25.51 | 25.75 | - | 24.0 |
| 106 | 12 | 27.69 | 27.70 | 27.69 | 27.60 | 27.68 | + | 27.0 |
| | 9 | 24.69 | 24.72 | 24.69 | 24.60 | 24.68 | - | 24.0 |

SPE 257

# TEST DATA SHEET

**Engineering Laboratory**

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED TEMPERATURE
E.C.I. PART NO. 03-02762
MFR. NAME ECI
PART NAME DC AMP, POWER SUPPLY

DATE 3-24-71
TESTED BY H. Stadnik
WITNESSED BY
APPROVED BY

POST TEMPERATURE FINE LEAK TEST

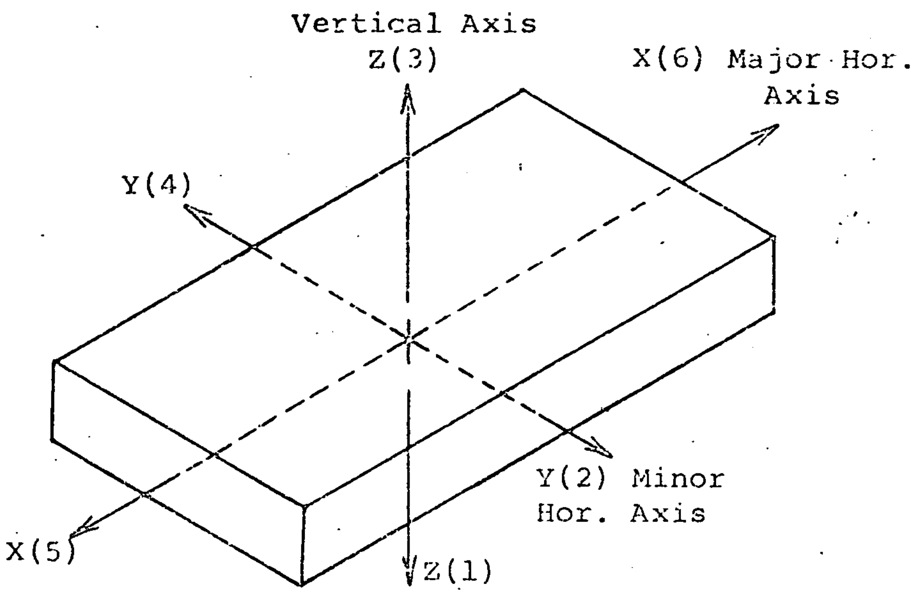
| S/N | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 101 | | $7 \times 10^{-10}$ | cc/s | | | | | |
| 102 | | $9 \times 10^{-10}$ | cc/s | | | | | |
| 103 | | $8 \times 10^{-10}$ | cc/s | | | | | |
| 104 | | $9 \times 10^{-10}$ | cc/s | | | | | |
| 105 | | $9 \times 10^{-10}$ | cc/s | | | | | |
| 106 | | $6 \times 10^{-10}$ | cc/s | | | | | |

SPE 257

Unit Identification & Serial No.
03-02672, S/N 101, 102 & 105
03-02762, S/N 103, 104 & 106

Date 4-14 & 4-16-71
Tested by C. Hammer
Witnessed by
Approved by

SHOCK




| DROP (NO) | DROP (DIR) | HT (IN) | MAG G's | PULSE (MS) | FILTER (CPS) |
|---|---|---|---|---|---|
| 1,2,3 | Z-1 | 19 | 100 | 11 | 250 |
| 4,5,6 | X-5 | 19 | 100 | 11 | 250 |
| 7,8,9 | X-6 | 19 | 100 | 11 | 250 |
| 10,11,12 | Y-4 | 19 | 100 | 11 | 250 |
| 13,14,15 | Y-2 | 19 | 100 | 11 | 250 |
| 16,17,18 | Z-3 | 19 | 100 | 11 | 250 |

# TEST DATA SHEET

**Engineering Laboratory**

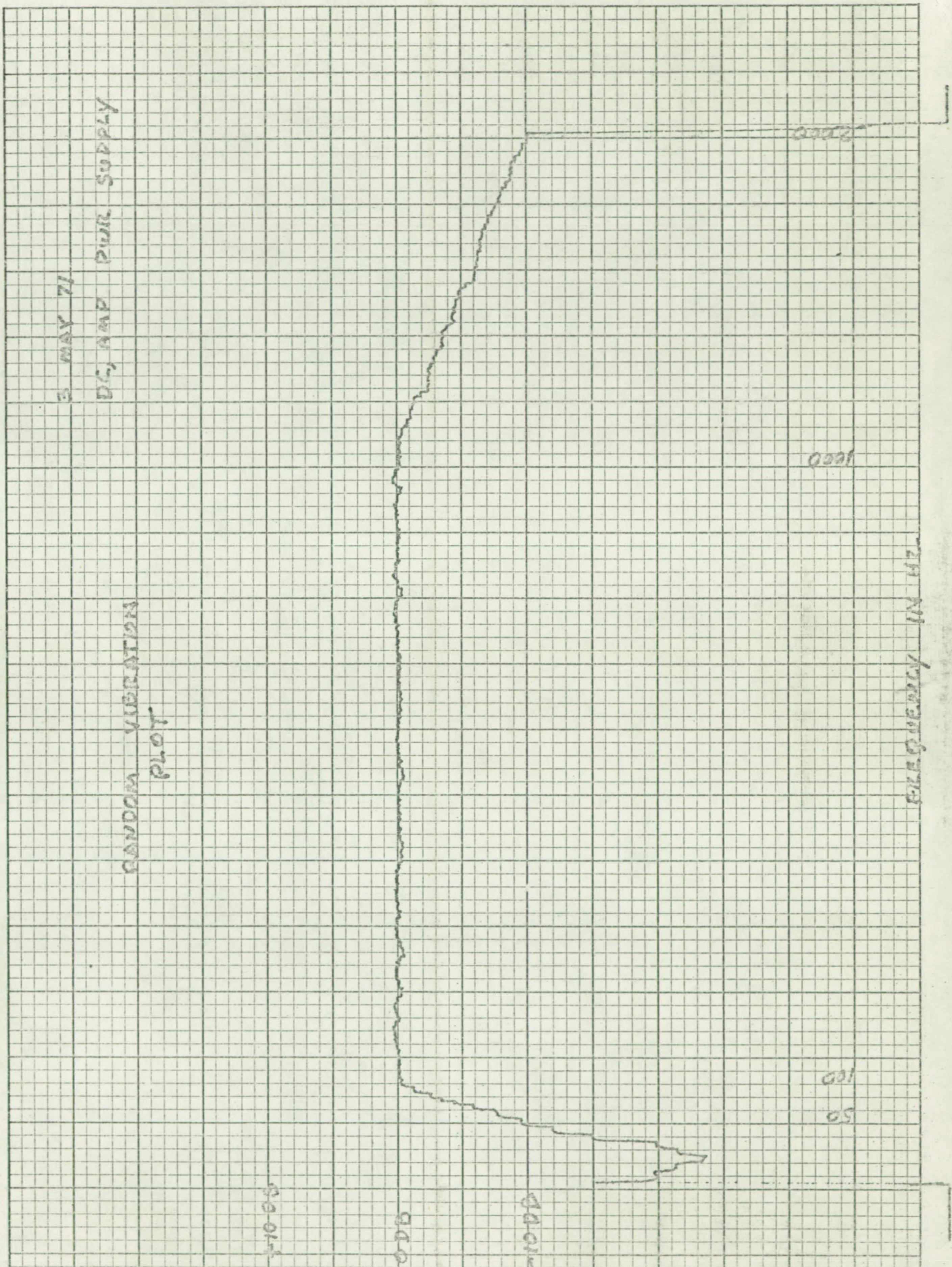
ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED: RANDOM VIBRATION
E.C.I. PART NO. 03-02762
MFR. NAME: E.C.I.
PART NAME: D.C. AMP, PWR SUPPLY

DATE: 3 MAY 71
TESTED BY: T Robinson
WITNESSED BY:
APPROVED BY:

| PLANE | LEVEL | TIME |
|---|---|---|
| VERT | 46.3GRMS | 30 MIN |
| HORIZ MI. | 46.3 GRMS | 30 MIN |
| HORIZ MAJ. | 46.3GRMS. | 30 MIN |

SPE 257


RANDOM VIBRATION
PLOT
3 MAY 71
DC, AMP PWR SUPPLY
FREQUENCY IN HZ
2000
1000
100
50
+10 DB
0 DB
-10 DB

# TEST DATA SHEET

**ENGINEERING LABORATORY**

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG, FLORIDA

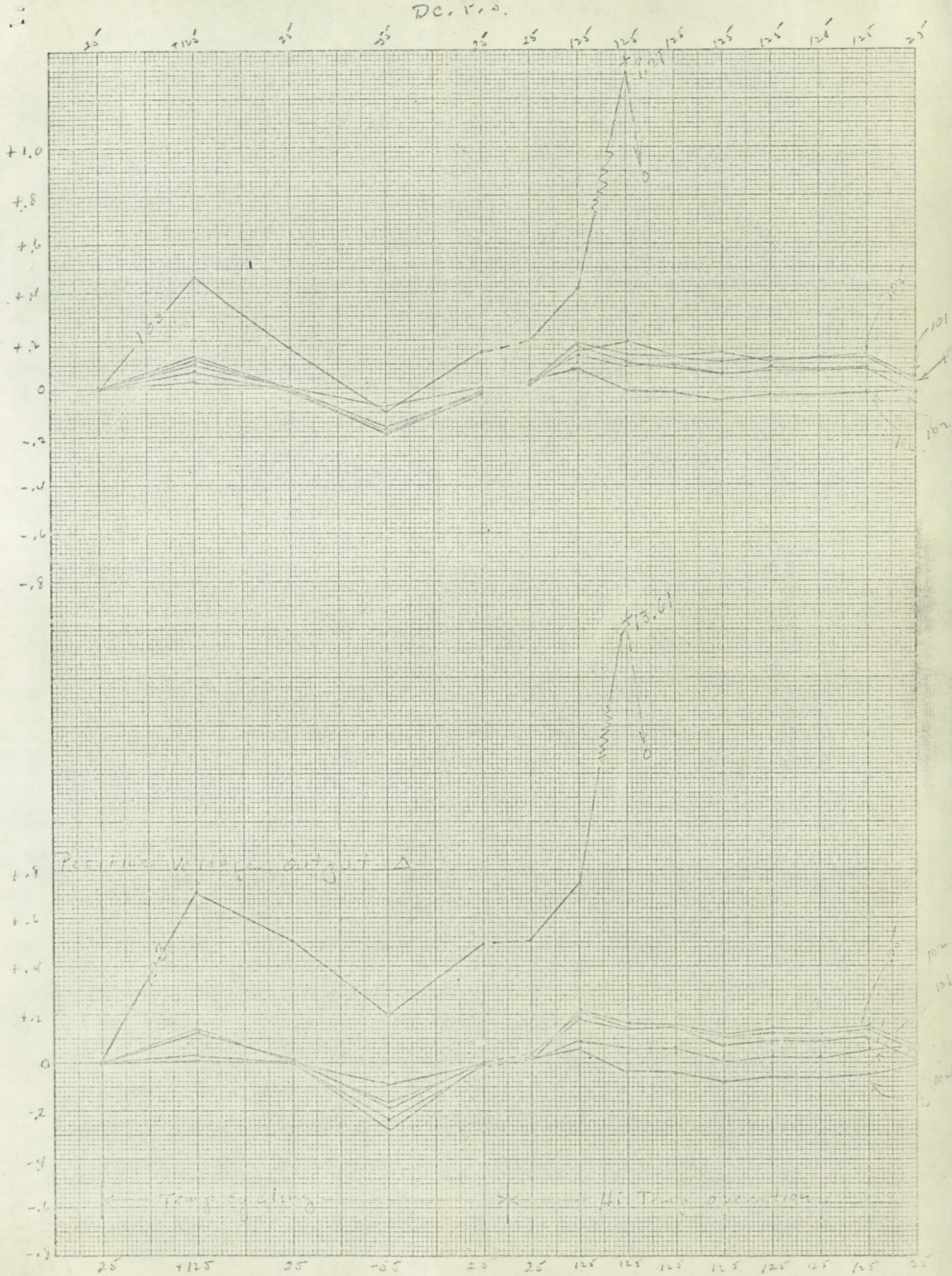
SUBJECT MICRO-MIN D.C. POWER SUPPLIES HI-TEMP OPERATION

DATE 5/14/71 WITNESSED BY [signature]
TESTED BY D. [signature] APPROVED BY

| TEMP. | | +25°C | +125°C | | | | | | | +25°C | SPEC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | DATE | 5/14 | 5/14 | 5/17 | 5/18 | 5/19 | 5/20 | 5/21 | 5/24 | 5/24 | |
| 101 | POS | +27.89 | +28.06 | +28.0 | +28.0 | +27.96 | +27.98 | +27.98 | +28.0 | +27.91 | +27v min |
| | NEG | -25.17 | -25.27 | -25.23 | -25.24 | -25.20 | -25.21 | -25.21 | -25.22 | -25.19 | -24v min |
| 102 | POS | +28.28 | +23.45 | +28.37 | +28.37 | +28.32 | +28.34 | +28.34 | +28.35 | +28.25 | +27v min |
| | NEG | -25.24 | -25.40 | -25.33 | -25.32 | -25.28 | -25.30 | -25.30 | -25.30 | -25.20 | -24v min |
| *103 | POS | +30.64 | +30.87 | +40.78 | — | — | — | — | — | | +27v min |
| | NEG | -27.37 | -27.58 | -36.44 | — | — | — | — | — | | -24v min |
| 104 | POS | +27.97 | +28.05 | +28.01 | +28.01 | +27.97 | +27.99 | +27.99 | +28.01 | +28.03 | +27v min |
| | NEG | -24.69 | -24.83 | -24.78 | -24.79 | -24.75 | -24.77 | -24.77 | -24.78 | -24.72 | -24v min |
| 105 | POS | +28.95 | +29.13 | +29.08 | +29.08 | +29.04 | +29.06 | +29.06 | +29.07 | +28.98 | +27v min |
| | NEG | -25.79 | -25.96 | -25.91 | -25.92 | -25.88 | -25.90 | -25.90 | -25.91 | -25.81 | -24v min |
| 106 | POS | +27.71 | +27.75 | +27.65 | +27.65 | +27.61 | +27.63 | +27.63 | +27.64 | +27.68 | +27v min |
| | NEG | -24.73 | -24.77 | -24.68 | -24.68 | -24.64 | -24.66 | -24.66 | -24.67 | -24.68 | -24v min |

*NOTE: 1. S/N 103 REMOVED FROM TEST 5/17/71

TR-112-S


DC. F.O.
Percentage Voltage Output Δ
Temp cycling
Hi Temp operation
10 X 10 TO THE CENTIMETER 46 1512
KEUFFEL & ESSER CO.

# TEST DATA SHEET

**ENGINEERING LABORATORY**

**ELECTRONIC COMMUNICATIONS, INC.**

ST. PETERSBURG, FLORIDA

**SUBJECT** D.C. AMPL. P/N 03-02457-001
S.S.T

**DATE** 16 JUNE 71 **WITNESSED BY** [signature]
**TESTED BY** D. [signature] **APPROVED BY**

| S/N | | | POST VIB SCAN | STEP #1 | STEP #2 | STEP #3 | STEP #4 | STEP #5 | STEP #6 | STEP #7 | STEP #8 | STEP #9 | STEP #10 | STEP #11 | | *OUTPUT SPECS (VOLTS) | | @ INPUT (VOLTS) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 112 | NULL | | +3.54MV | +20.03 | +21.57 | +22.69 | +19.52 | +18.32 | +17.76 | +18.41 | +17.58 | +18.36 | +17.76 | +19.07 | | 15mV | | 0 | |
| | + OUT | | +45.06 | +44.98 | +44.97 | +44.99 | +29.43 | +28.85 | +28.81 | +28.88 | +28.72 | +28.61 | +28.80 | +28.94 | | 45.0±1% | | 9.00 | |
| | - OUT | | -45.01 | -44.95 | -44.94 | -44.96 | -29.64 | -28.91 | -28.73 | -28.98 | -28.63 | -28.70 | -28.63 | -29.0 | | 45.0±1% | | 9.00 | |
| | | | | | | | | | | | | | | | | | | | |
| 114 | NULL | | -1.64MV | +1.37 | +1.56 | -0.52 | +0.44 | +1.72 | +1.01 | +0.98 | +1.11 | +1.48 | +1.45 | +1.07 | | 15mv | | 0 | |
| | + OUT | | +45.04 | +44.96 | +44.97 | +44.97 | +44.99 | +44.98 | +44.97 | +44.98 | +44.98 | +44.93 | +44.92 | +44.98 | | 45.0±1% | | 9.00 | |
| | - OUT | | -45.03 | -44.97 | -44.97 | -44.98 | -45.01 | -44.99 | -44.98 | -44.99 | -44.99 | -44.93 | -44.96 | -45.0 | | 45.0±1% | | 9.00 | |
| | | | | | | | | | | | | | | | | | | | |
| 117 | NULL | | -3.99MV | -2.89 | -3.14 | -2.34 | -2.91 | -3.06 | -3.12 | -2.74 | -2.90 | -2.82 | -3.03 | -2.31 | | 15mv | | 0 | |
| | + OUT | | +45.04 | +44.95 | +44.94 | +44.96 | +44.98 | +44.97 | +44.97 | +44.98 | +44.97 | +44.90 | +44.98 | +44.98 | | 45.0±1% | | 9.00 | |
| | - OUT | | -45.04 | -44.96 | -44.96 | -44.98 | -44.99 | -44.99 | -44.99 | -44.99 | -44.99 | -44.94 | -45.0 | -45.0 | | 45.0±1% | | 9.00 | |

* 45±1% = 44.55 V ⟶ 45.45
3mv null referred to input with closed loop gain adj. to 5 yields a max null of 15mv

TR-112-S

# TEST DATA SHEET

**Engineering Laboratory**

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED S.S.T.
E.C.I. PART NO.
MFR. NAME
PART NAME D.C. PWR. SUPPLY

DATE 16 June 71
TESTED BY D. [illegible]
WITNESSED BY [illegible]
APPROVED BY

| | S/N 101 | | S/N 102 | | S/N 104 | | | |
|---|---|---|---|---|---|---|---|---|
| STEP # | +OUT | -OUT | +OUT | -OUT | +OUT | -OUT | | |
| VIB. SCAN | 27.94 | 25.23 | 28.27 | 25.22 | 28.05 | 24.74 | | |
| 1 | 27.89 | 25.19 | 28.25 | 25.20 | 28.03 | 24.72 | | |
| 2 | 27.89 | 25.18 | 28.24 | 25.19 | 28.02 | 24.72 | | |
| 3 | 27.90 | 25.18 | 28.24 | 25.20 | 28.03 | 24.72 | | |
| 4 | 27.91 | 25.19 | 28.26 | 25.21 | 28.04 | 24.73 | | |
| 5 | 27.88 | 25.17 | 28.23 | 25.18 | 28.01 | 24.70 | | |
| 6 | 27.89 | 25.18 | 28.24 | 25.19 | 28.02 | 24.72 | | |
| 7 | 27.89 | 25.18 | 28.24 | 25.19 | 28.02 | 24.71 | | |
| 8 | 27.89 | 25.17 | 28.24 | 25.19 | 28.03 | 24.72 | | |
| 9 | 27.89 | 25.17 | 28.23 | 25.18 | 28.02 | 24.71 | | |
| 10 | 27.91 | 25.19 | 28.25 | 25.20 | 28.04 | 24.72 | | |
| 11 | 27.90 | 25.18 | 28.25 | 25.19 | 28.04 | 24.73 | | |
| SPEC | +27v min | -24v min | +27v min | -24v min | +27v min | -24v min | | |

SPE 257